

## *Operational Space Weather Data*



# **COSPAR 2012**

**W. Denig, J. Green, J. Rodriguez &  
R. Viereck**

**U.S. Department of Commerce  
National Oceanic and Atmospheric  
Administration (NOAA)**



# Operational SWx Data Topics



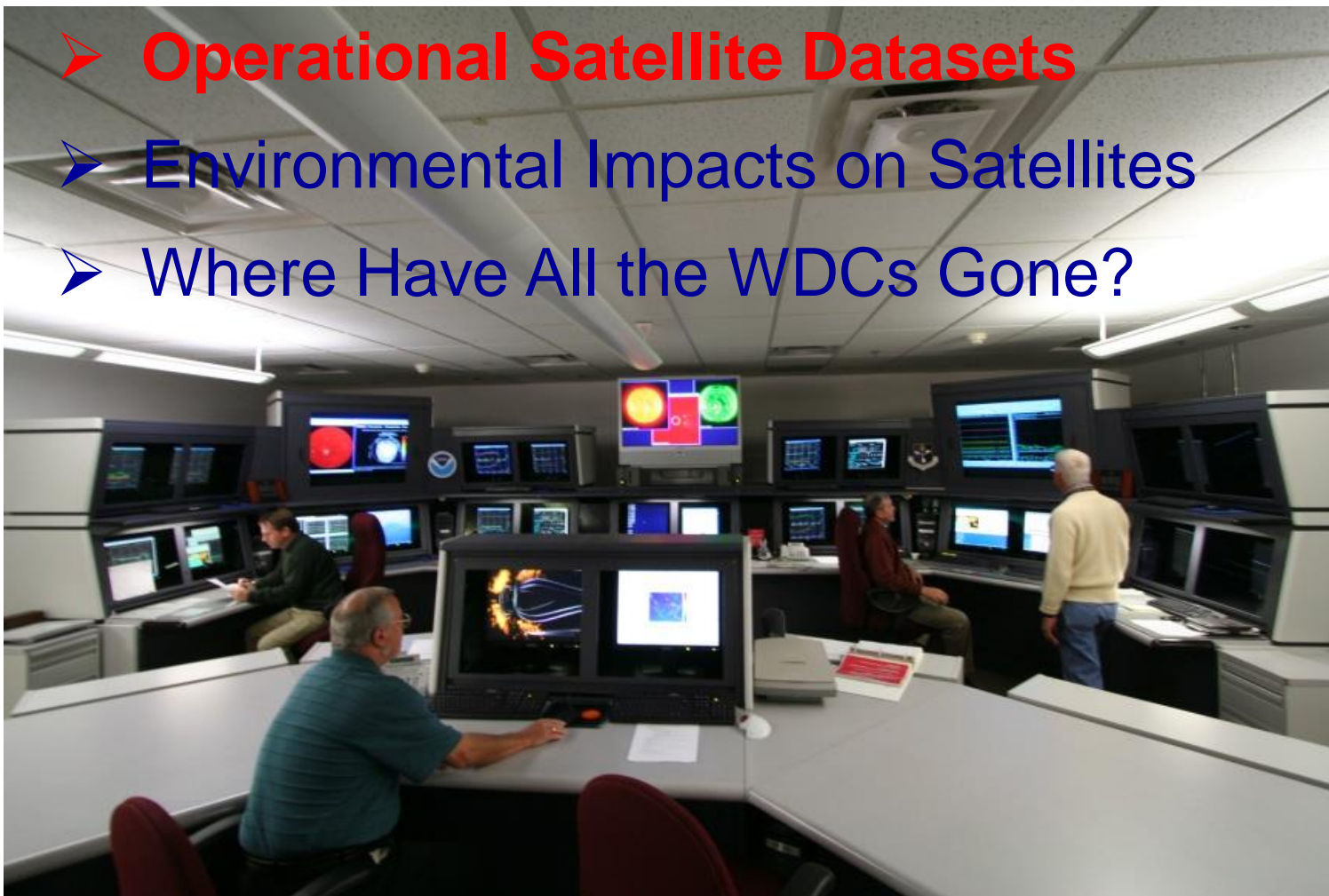
- **Operational Satellite Datasets +**
- **Environmental Impacts on Satellites**
- **Where Have All the WDCs Gone?**



Auroral Photograph by Jim Spann  
Chapman Conference, Fairbanks (AK) 2011

# Operational SWx Data Topics

- **Operational Satellite Datasets**
- Environmental Impacts on Satellites
- Where Have All the WDCs Gone?



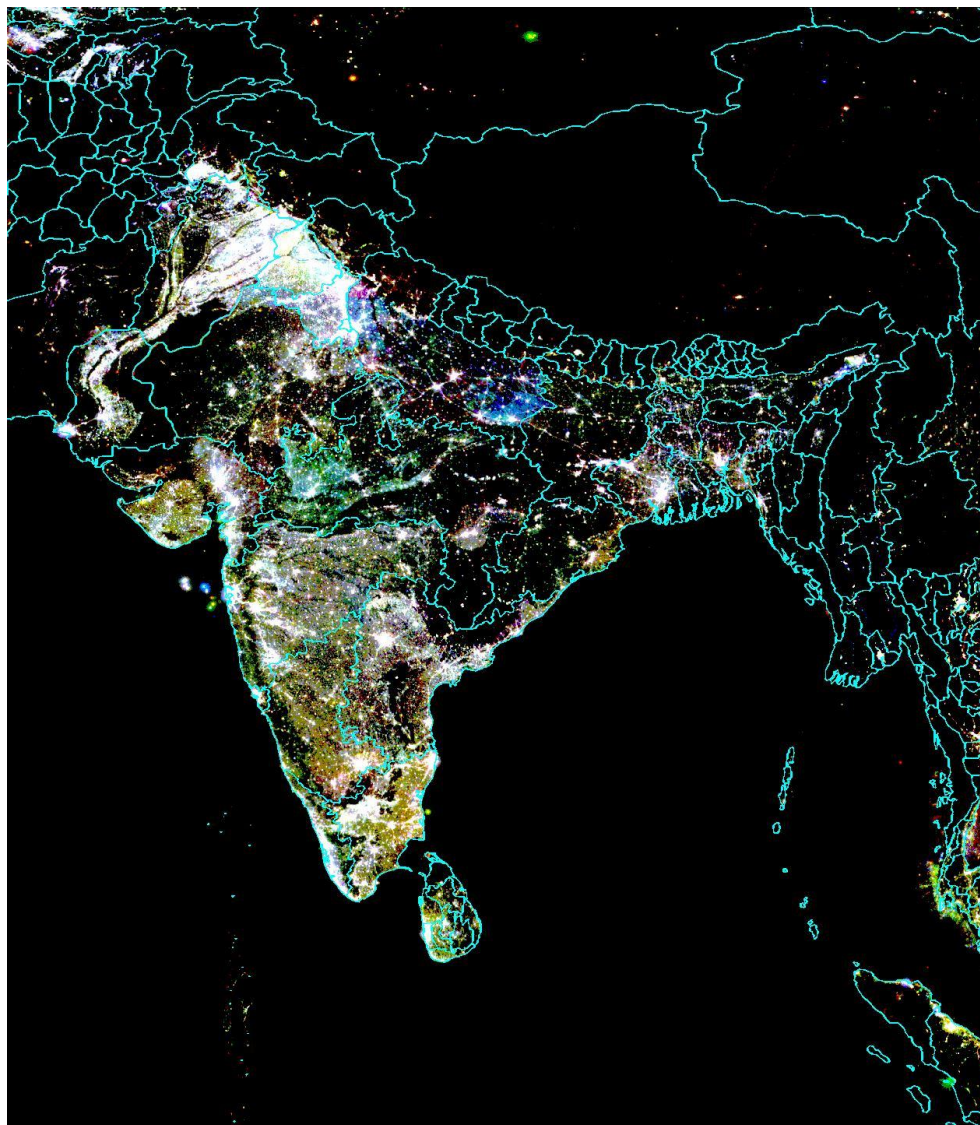
Space Weather Forecast Office  
Boulder, Colorado





# Operational SWx Data

## Nighttime Light Change - India



### Non Space Weather Use of Operational Data

Color composite of DMSP-OLS nighttime lights of India.

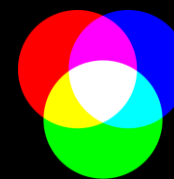
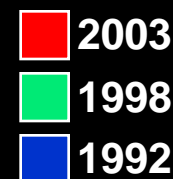
**1992 blue**

**1998 green**

**2003 red**

Contrast enhanced. Colors indicate changes in lighting among the three years. Indications are that between 1992 and 2003 there was a substantial expansion in nighttime lighting, particularly in rural areas and the outer extents of cities.

Key





# Operational SWx Data

## Nighttime Light Change – Karnataka



You are here



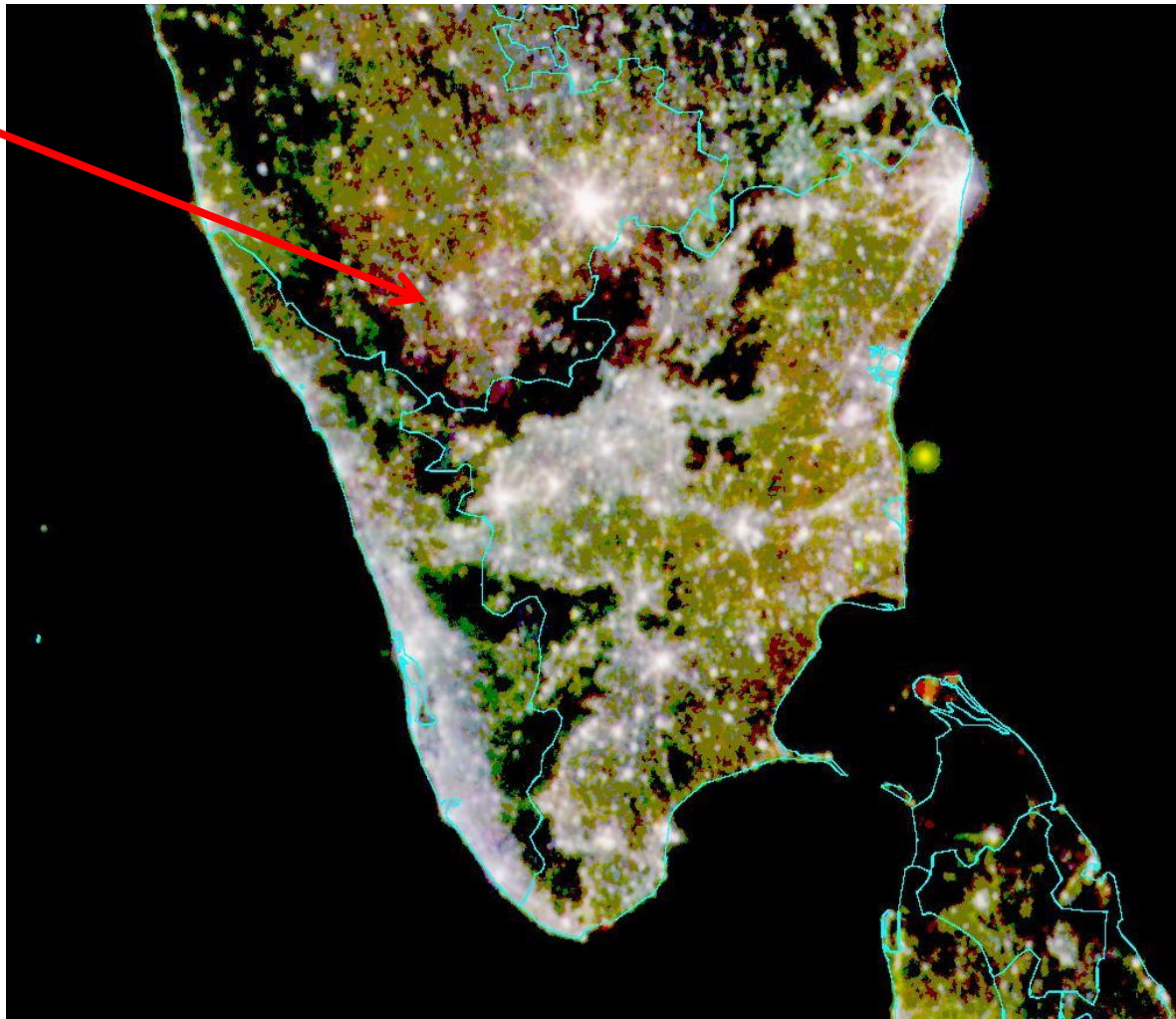
Narayana Murthy  
Center of Excellence

Key

2003

1998

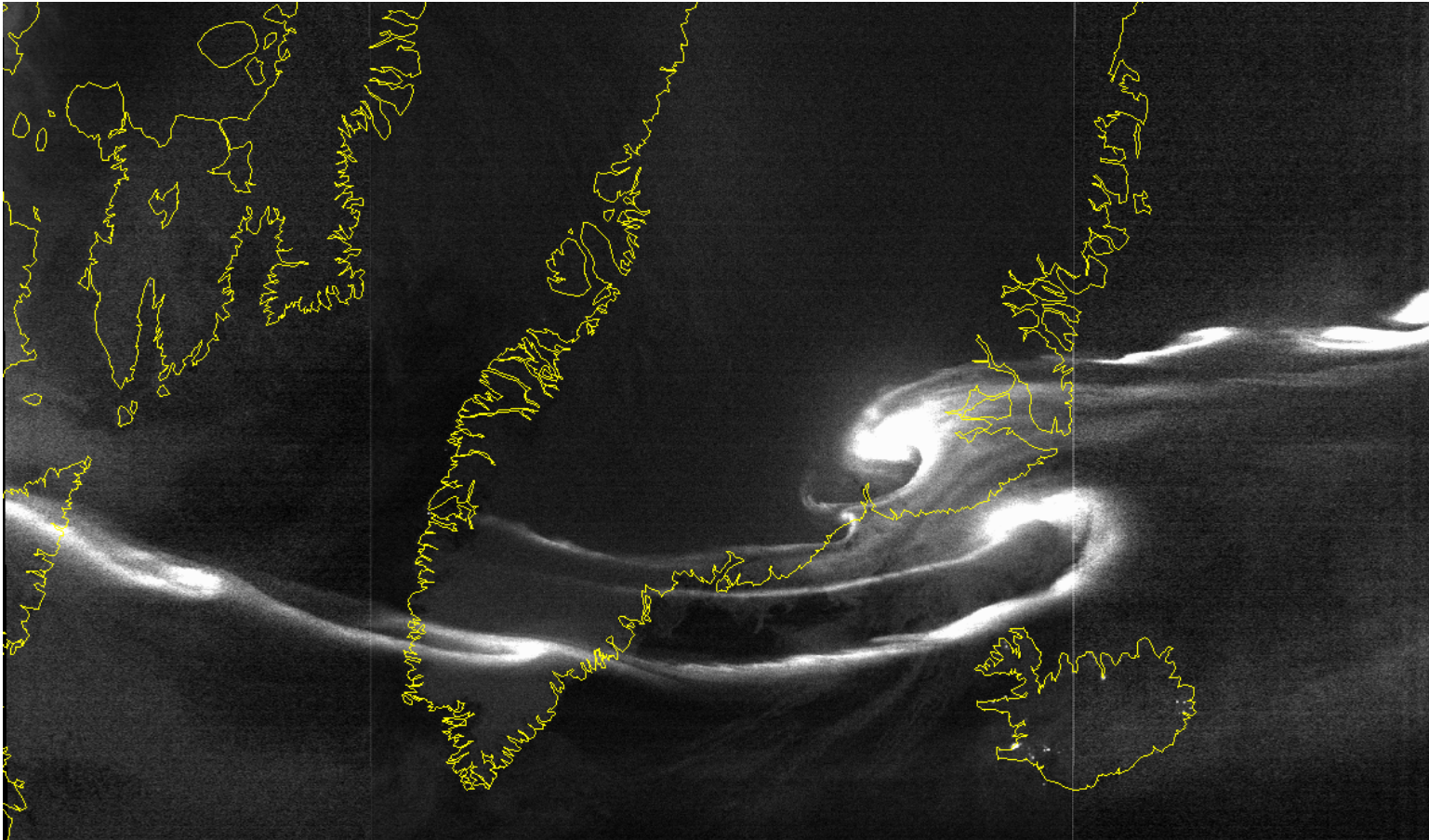
1992





# Operational SWx Data

## Same Sensor – Different Application



White light auroral image (westward traveling surge) from the Operational Linescan System (OLS) on the Defense Meteorological Satellite Program (DMSP). OLS was originally designed to image clouds.



# Operational SWx Data

## Same Sensor – Different Application



VOL. 79, NO. 7

JOURNAL OF GEOPHYSICAL RESEARCH

MARCH 1, 1974

### Satellite Observations of Auroral Substorms

C. P. PIKE AND J. A. WHALEN

*Air Force Cambridge Research Laboratories, Bedford, Massachusetts 01730*

Satellite photographs of auroras obtained from a polar-orbiting U.S. Air Force satellite were used to study auroral substorms in the premidnight time sector during and after a geomagnetic storm period. The photographs provide a unique means of seeing in detail the interrelationship between discrete, continuous/diffuse, and polar cap auroras during a period of frequent occurrence of substorms. The distributions of discrete auroras seen in the satellite photographs further substantiate the Feldstein auroral oval concept and the Akasofu auroral substorm concept. However, the photographs suggest that the continuous aurora and polar cap auroras have not been adequately accounted for in the present concepts of auroral substorm morphology.

During a period of frequent occurrence of auroral substorms, auroral morphology in the premidnight sector was studied using satellite photographs of auroras obtained from a polar-orbiting U.S. Air Force satellite. The U.S. Air Force Air Weather Service Data Acquisition and Processing Program provided these photographs to the Air Force Cambridge Research Laboratories (AFCLR) for analysis. A sequence of satellite photographs of auroras recorded during and after a geomagnetic storm period (November 24–28, 1971) was selected for analysis. The photographs presented in this paper provide detailed observations of new relationships between discrete, polar cap, and continuous/diffuse auroras. The continuous aurora [Whalen *et al.*, 1971] was clearly identified during airborne ionospheric and optical observations in the noon sector of the auroral oval. The continuous aurora, which was detected simultaneously by the airborne photometer as a nondiscrete component of  $N_2^+$  and by the airborne ionospheric sounder as an  $E$  layer, extends equatorward for several degrees from the instantaneous position of the discrete midday auroral oval. The height of the  $E$  layer, which is associated with the continuous aurora, corresponds to atmospheric stopping heights for 1.0–3.0 keV electrons. Subsequent airborne observations in other time sectors of the auroral oval have shown that the auroral  $E$  layer continuous aurora occurred in an uninterrupted circumpolar belt [Wagner and Pike, 1972; Buchau *et al.*, 1972]. The Isis 2 scanning photometer (3914 Å, 5577 Å) has also mapped out the latitudinal and the local time extent of the continuous/diffuse aurora and has verified that the continuous/diffuse aurora lies in an uninterrupted circumpolar belt, the 'diffuse auroral belt' [Lui and Anger, 1973].

In this paper the satellite photographs of auroras are used to further substantiate Feldstein's auroral oval concept [Feldstein, 1963; Feldstein and Starkov, 1967] and Akasofu's auroral substorm concept [Akasofu, 1964, 1968].

#### DATA

The auroral photographs are obtained from a military satellite, part of the Department of Defense Defense Systems Application Program. The satellite has a circular orbit of about 800 km. The photographs are produced by a line-scanning technique in which the field of view of the

detector is swept repeatedly across the earth, perpendicular to the path of the satellite and through the subsatellite point. The scan repetition rate and the field of view are adjusted so that the forward motion of the satellite in its orbit carries it a distance corresponding to the width of the field of view on the earth between successive scans. The scans thus form a raster that composes the photographs. The orbital period of the satellite is 101 min, so that the time required to transmit and hence to generate a photograph 10° in latitudinal extent (which is a width typical of the auroras reported here) is 2.8 min. The field of view at the subsatellite point is 3.7 km at the surface of the earth and about 3.2 km at 100-km altitude. The longitudinal width of the photographs is approximately 3000 km at the surface of the earth and about 2500 km at 100-km altitude. The spectral range of the detector is approximately 0.45–1.1  $\mu$  [Morse *et al.*, 1973]. The minimum detectable auroral brightness is estimated to be  $IBC \sim I$ ; saturation brightness is estimated to be  $IBC \sim III$  (A. L. Snyder, private communication, 1973). The presence of moonlight apparently raises the detection threshold considerably. Auroras appear to brighten progressively from the center to the edge of the photographs as a result of the Van Rijn effect, the increase in optical thickness with increasingly oblique viewing angle.

Photographs presented here were obtained on the nighttime when the satellite was in the 0800–2000 local time orbital plane traveling from north to south. In all the photographs the geographic north pole is marked with a star, and the corrected geomagnetic latitude/corrected geomagnetic local time (CGL/CGLT) is labeled. (The CGL/CGLT coordinate system for ground level [Hultqvist, 1958; Hakura, 1965] is used in this paper.) Solar illumination of the satellite causes the solid white area seen in the upper portion of the photographs. City lights are seen in the photographs, and some cities in Russia (Magadan, Yakutsk, and Nikolayevsk-na-Amure) and in Alaska (Anchorage and Fairbanks) are labeled to point out the spatial extent and resolution of the photographs.

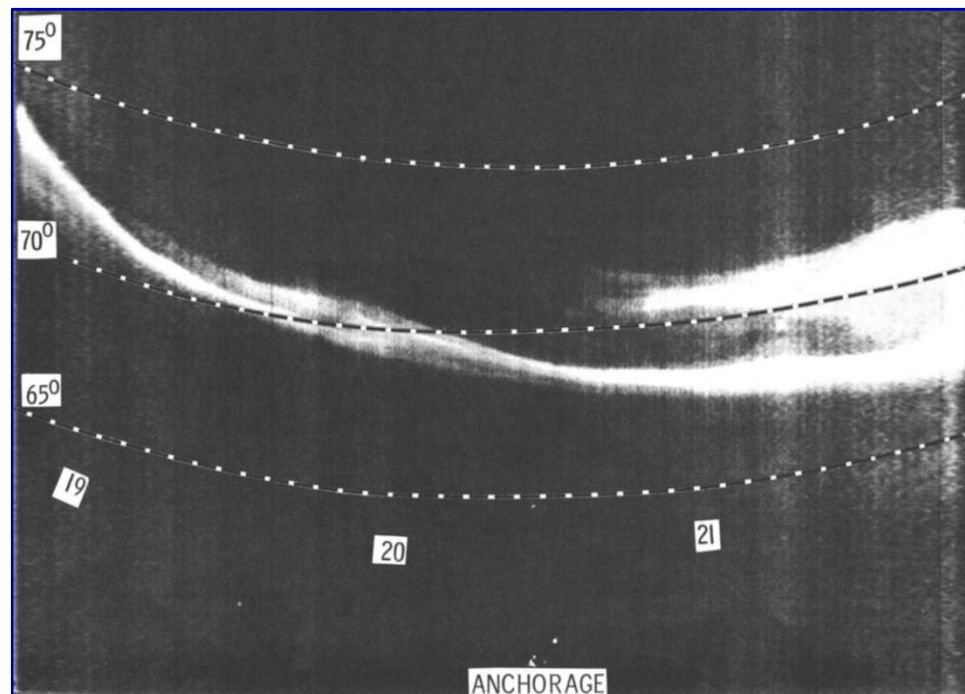
Table 1 lists dates and times when the auroral photographs used in this paper were recorded. The exact beginning and end times when auroras were seen in the photographs are also given. All photographs recorded during and after the geomagnetic storm period (November 24–28, 1971) are presented here, and all photographs show auroras.

Copyright © 1974 by the American Geophysical Union.

985

### First use of operational data for space research

Nighttime imagery from the OLS was used to study the morphology of substorms in the pre-midnight time sector. Imagery was used to substantiate the Feldstein auroral oval and the Akasofu auroral substorm concepts. JGR reprint on the left is from Pike and Whalen [1974].



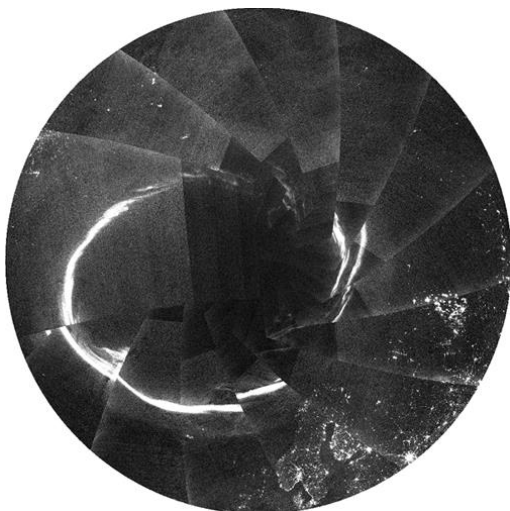


# Operational SWx Data

## OLS Used to Identify the Auroral Boundary

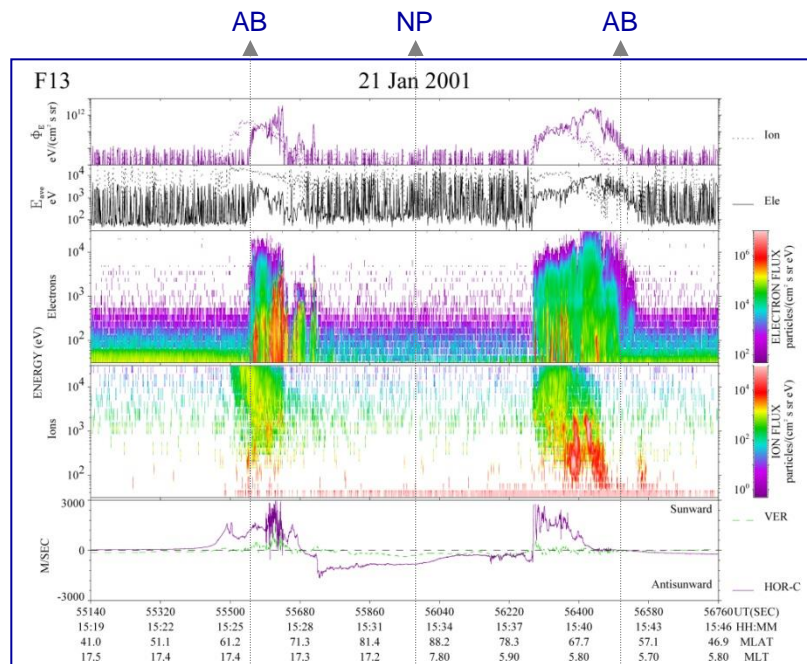
- Historical operational methods used white-light imagery data from the DMSP Operational Linescan System (Pike & Whalen [1974] see also Meng [1976]).
- Auroral boundary identification monitoring has now transitioned to a particle-based approach using the DMSP SSJ series of sensors (see *Gussenhoven et al.* [1987]).
- Current alternative approaches include ultra-violet (UV) imaging of the auroral zone.

24-hour auroral composite  
from DMSP OLS



Credit: Elvidge, NOAA/NGDC

DMSP polar pass using the SSJ



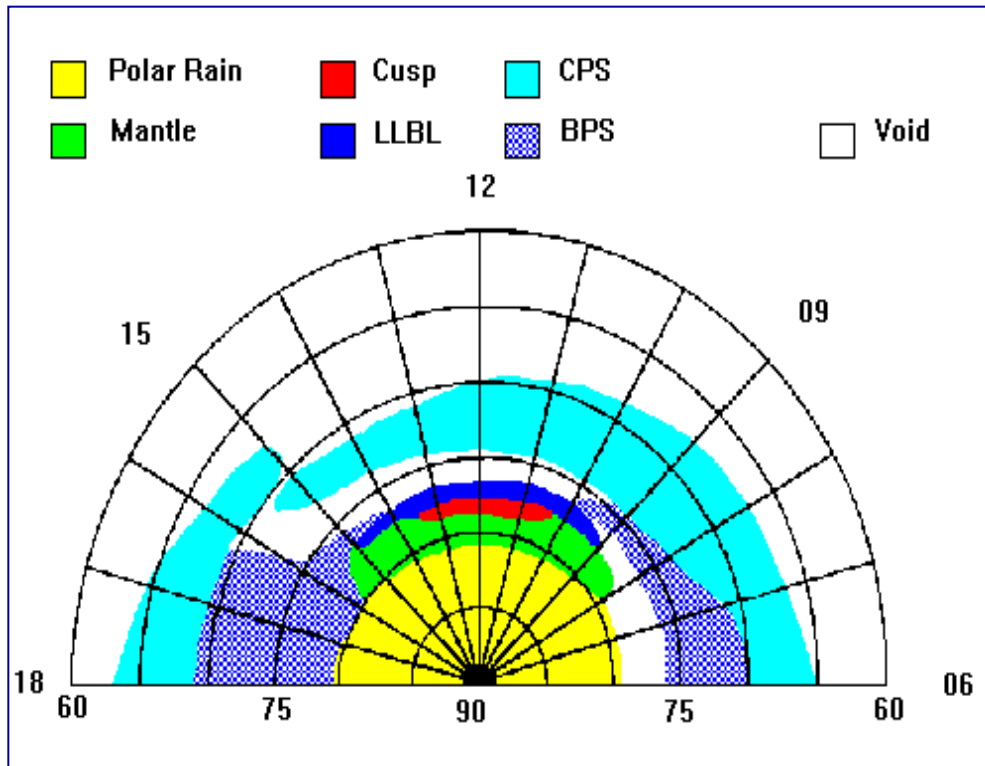
Credit: Denig, AFRL



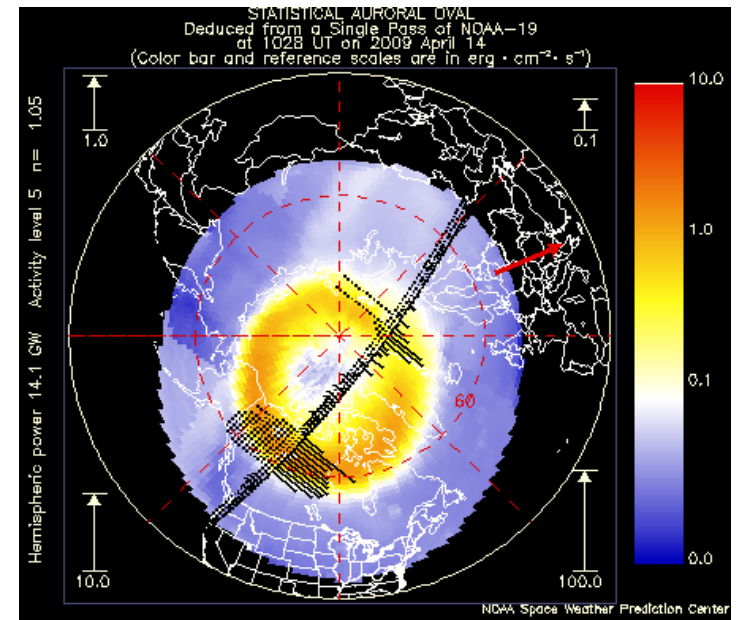
## LEO Measurements – Auroral Morphology

### Auroral Energy Particles

Measure the energy spectrum and distribution of particles precipitating into the high-latitude ionosphere. Discern magnetospheric source regions in magnetic latitude - magnetic local time plots.

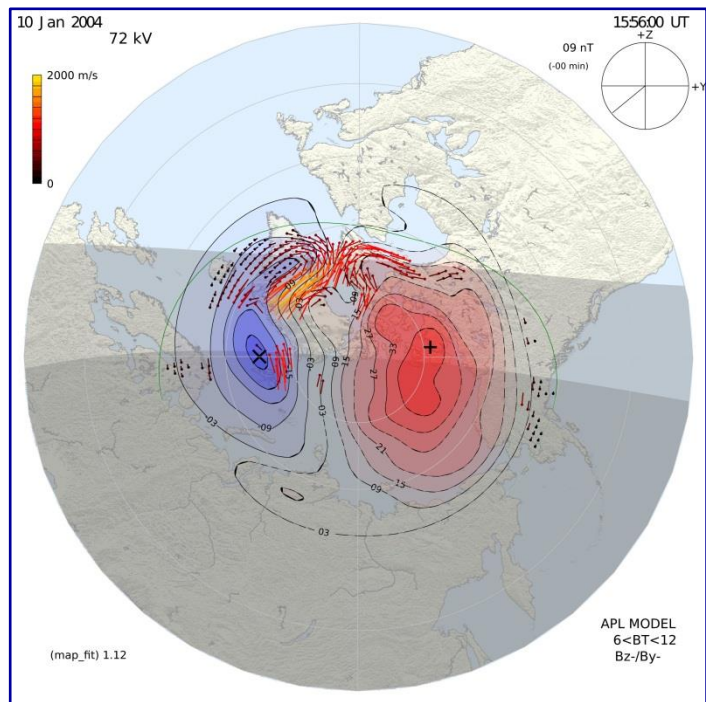


Credit: Newell, JHU/APL



# Operational SWx Data

## Extended Capabilities – LEO Data



Andalsvik et al., 2011

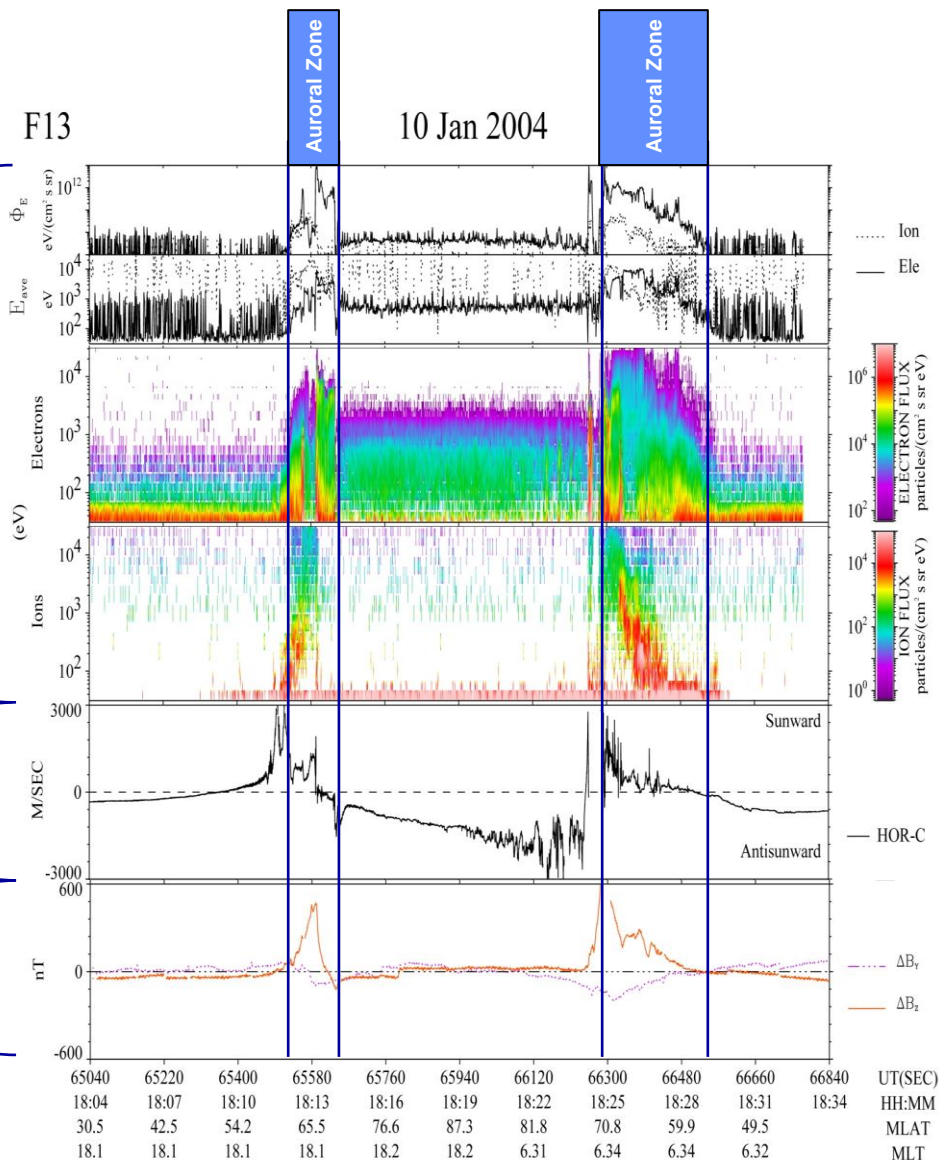
### LEO measurements

SWx data from the DMSP are used to determine the electrodynamics of the high-latitude space environment.

Particles

Convection

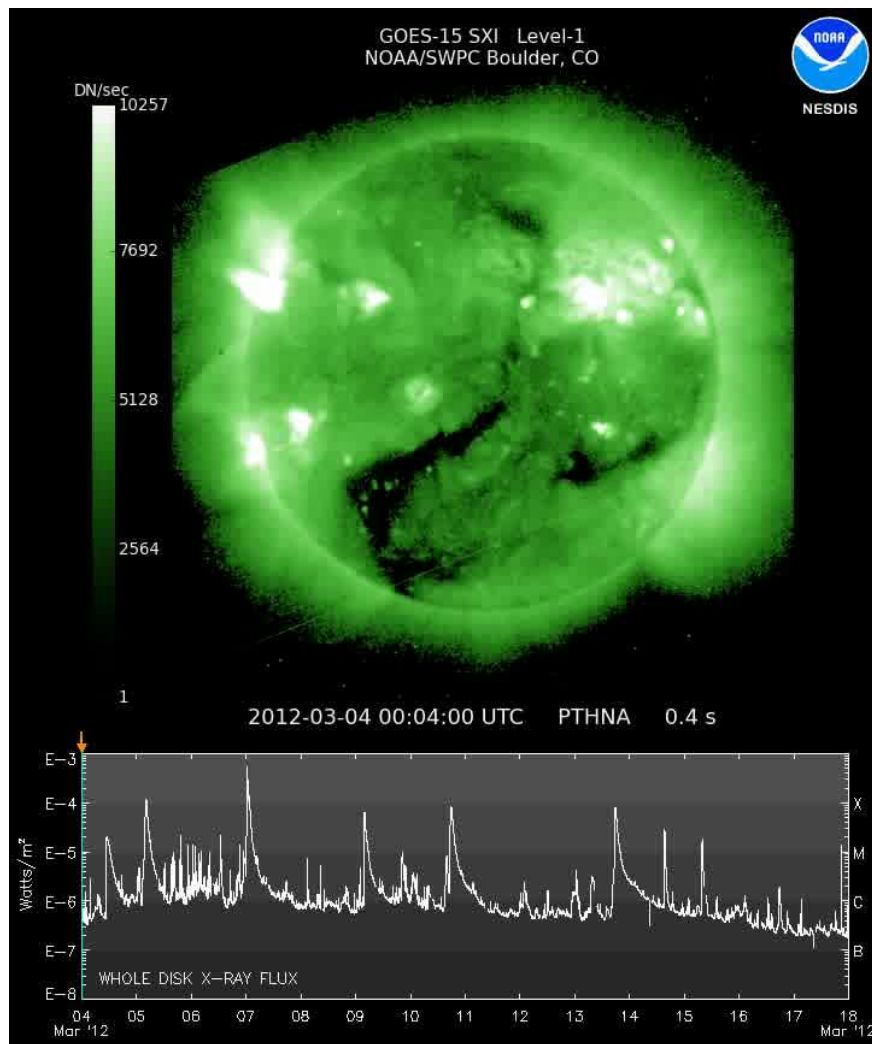
Field  
Aligned  
Currents





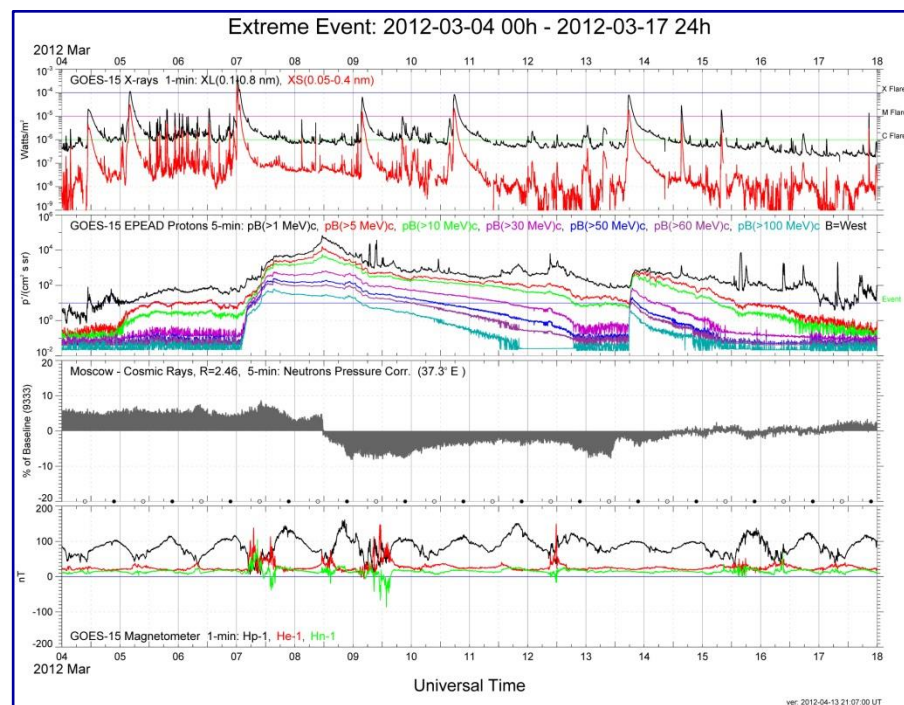
# Operational SWx Data

## GOES SWx Data – March 2012



### GEO Measurements

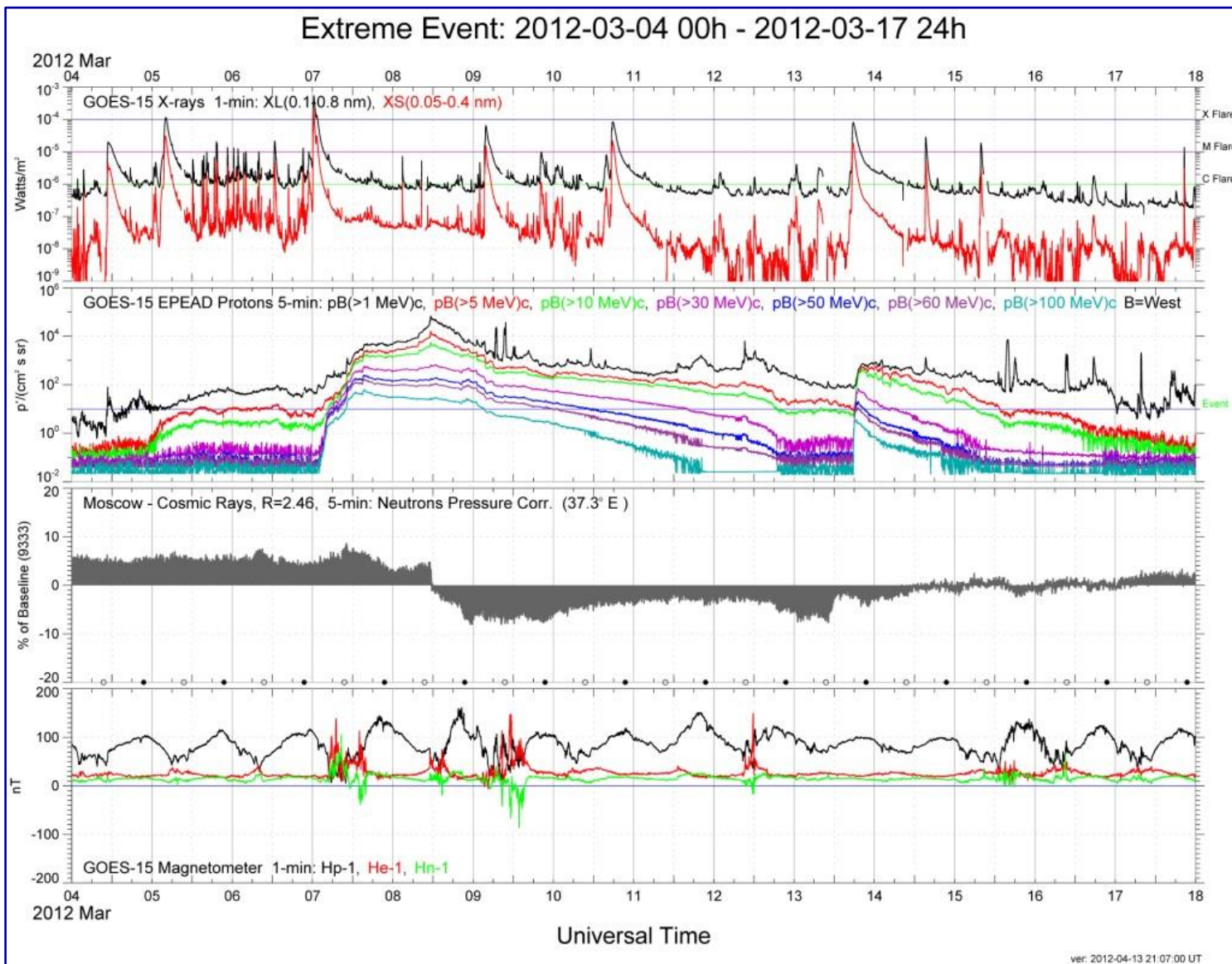
Space weather data from Geostationary Operational Environmental Satellites (GOES) include space particle and field measurements plus solar observations.



All data and plots are available at: <http://www.ngdc.noaa.gov/stp/satellite/satdataservices.html>

# Operational SWx Data

## A closer look at the 07 March event







# Operational SWx Data

## Over 35 Years of Operational SWx Data



Over 35 years of operational satellite space environmental data are available for heliophysics research. For the most part the measurement parameters have remained the same except for some improvements in sensor design and performance.

NOAA GOES – particles, fields, solar observation

Date range: 1976 – present

# of satellites: 15 (not counting 1 failure)

<http://www.ngdc.noaa.gov/stp/satellite/goes/index.html>

<http://sxi.ngdc.noaa.gov/>

NOAA POES (also MetOp) – energetic charged particles

Date range: 1978 – present

# of satellites: 12 (not counting 1 launch failure)

<http://www.ngdc.noaa.gov/stp/satellite/poes/index.html>

USAF DMSP – energetic particles & fields

Date range: 1976 – present

# of satellites: 13

<http://www.ngdc.noaa.gov/nndc/struts/results?t=102827&s=1&d=1001,1002,9>

*It keeps going and going and going*

Data available through the NOAA National Geophysical Data Center (<http://www.ngdc.noaa.gov/ngdc.html>)

# Operational SWx Data

## Other Ground Assets



USAF Ionosonde Network (**MIRION**) – Boulder, CO  
<http://www.ngdc.noaa.gov/stp/iono/ionohome.html>



USGS Magnetic Observatories<sup>1</sup>  
(**INTERMAGNET**) – Barrow, AK  
<http://spidr.ngdc.noaa.gov/spidr/>



USAF Solar Electro-Optical Network (**SEON**)  
<http://www.ngdc.noaa.gov/stp/spaceweather.html>

<sup>1</sup>INTERMAGNET home page: <http://www.intermagnet.org/>  
USGS Geomagnetism: <http://geomag.usgs.gov/>



# Operational SWx Data

## Future Capabilities – GOES-R

The GOES-R series space/solar sensors provide an incremental improvement to current NOAA GEO space weather monitoring. The first launch date of the GOES-R series is 2015.



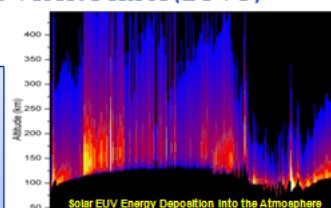
Credit: Lockheed-Martin

### Solar X-Ray Sensor (XRS)

- Measures the irradiance (total brightness) of the sun in two x-ray channels
  - 0.05 to 0.4 nm
  - 0.1 to 0.8 nm
- Provides a first alert of impending solar storms and space weather events.
- Observes solar flares and provides absolute brightness information.
- Drives space weather scales and operational models.

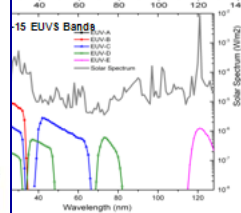
### Solar Extreme Ultra-Violet Sensor (EUVS)

- Observations of the Solar EUV Spectrum from 5 to 125 nm
- Provides solar EUV input to thermosphere and ionosphere models which provide specification and forecasts
- Models provide specification and



### Solar Ultra-Violet Imager (SUVI)

- Completely Different than GOES NOP:
- GOES NOP SXI observes in x-rays (0.8-6 nm)
  - SUVI will observe in the Extreme Ultra-Violet (EUV) (10-30 nm)
  - Narrow band EUV imaging: Permits better discrimination between features of different temperatures
  - 30.4 nm band adds capability to detect filaments and their eruptions
  - 6 wavelengths (9.4, 13.1, 17.1, 19.5, 28.4, and 30.4 nm) 2 minute refresh for full dynamic range
  - SUVI will provide
    - Flare location information (Forecasting event arrival time and geo-effectiveness)
    - Active region complexity (Flare forecasting)
    - Coronal hole specification (High speed solar wind forecasting)



Increased # of wavelength bands

### Space Environment In-situ Sensor Suite SEISS

Four Subsystems  
Measuring Electrons, Protons, and Heavier Particles

#### MPS-Low: Spacecraft charging, ground-induced currents (electric power grid)

- 30eV-30keV electrons
- 30eV-30keV protons
- 14 angular bins

#### MPS-High: Spacecraft charging, deep dielectric charging

- 40keV-4MeV electrons
- 80keV-10MeV protons
- 10 energy bands at 5 angles

#### SGPS: Solar Energetic Particle events (SEP), solar radiation storms (protons), HF communication (airlines), astronaut radiation, satellite degradation.

- 1 MeV-500MeV protons
- 4MeV-500MeV alphas
- 10 energy bands at 2 angles

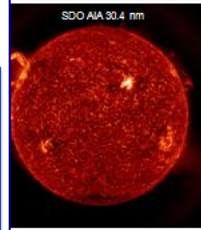
#### EHS: Satellite single event upsets, astronaut radiation

- 10MeV/nucleon-200MeV/nucleon
- Distinguishes H, He, C-N-O, Ne-S and the Fe group, Z=17-28
- 5 energy bands

#### SEISS Algorithms

- SEISS.16: One-minute averages - all MPS channels
- SEISS.17: Five-minute averages - all MPS and SGPS channels
- SEISS.18: Convert differential proton flux values to integral flux values
- SEISS.19: Density & temperature moments & level of spacecraft charging
- SEISS.20: Event detection based on flux values

provides improved proxy data: many pixels as SUVI cadence in 8 EUV bands, 5 of which match SUVI exactly



Solar UV imagery versus soft x-rays

Improved particle energy coverage



# Operational SWx Data

## Future Datasets – DSCOVR & COSMIC-2

### DSCOVR



Credit: NASA

#### Deep-space Climate Observatory

- Operational replacement for ACE
- Partnership with NASA and U.S. Air Force
- Solar-wind & magnetic field measurements @ L1
- Data stewardship & archive: NGDC
- Scheduled launch: 2014

ACE – Advanced Composition Explorer (NASA)

### COSMIC-2



Credit: Orbital Sciences Corp

#### Constellation Observing System for Meteorology, Ionosphere and Climate-2

- Operational replacement for COSMIC
- Partnership with Taiwan and the U.S. Air Force
- Improved weather forecasting drives the need
- Ionospheric specification and scintillation
- Data Stewardship and archive: NGDC/NCDC
- Scheduled launch: 2015

COSMIC – Constellation Observing System for Meteorology, Ionosphere and Climate





# Operational SWx Data Topics



- Operational Satellite Datasets
- **Environmental Impacts on Satellites**
- Where Have All the WDCs Gone?



Galaxy15 Satellite Anomaly 05 April 2010  
Photo Credit: [Business Wire](#)

# Operational SWx Data

## Environmental Impacts – Case 1

### Galaxy 15 Geostationary Satellite Anomaly – 05 April 2010

**SPACE NEWS** 29th Annual International Space Dev Chicago May 27 - 31 2010 National Space Society

Home Launch Contracts Civil Military **Satellite Telecom** Earth Observation Venture Space Policy

**CASBAA Singapore Satellite Industry Forum 2010** 14 June 2010 Shanori-La Singapore

04/08/10 02:33 PM ET  
**Intelsat Loses Contact with Galaxy 15 Satellite**  
By Warren Ferster

WASHINGTON — Intelsat's five-year-old Galaxy 15 satellite stopped responding to commands early April 5, prompting the company to begin moving an on-orbit spare to the balky satellite's 133 degrees west longitude orbital slot to avoid an interruption in service, Intelsat of Washington and Luxembourg announced April 8.

Intelsat spokesman Dianne VanBeher

Galaxy 15 satellite. Credit: Orbital Sciences' photo

[Enlarge Image](#)

**SPACE NEWS** 29th Annual International Space Dev Chicago May 27 - 31 2010 National Space Society

Home Launch Contracts Civil Military **Satellite Telecom** Earth Observation Venture Space Policy

**CASBAA Singapore Satellite Industry Forum 2010** 14 June 2010 Shanori-La Singapore

04/20/10 02:05 PM ET  
**Orbital Blames Galaxy 15 Failure on Solar Storm**  
By Peter B. de Selding

PARIS — The in-orbit failure of the Orbital Sciences-built Intelsat Galaxy 15 telecommunications satellite April 5 was likely caused by unusually violent solar activity that week that damaged the spacecraft's ability to communicate with ground controllers, Orbital officials said April 20.

Similar events have occurred, if less severely, on other Orbital spacecraft

Galaxy 15 satellite. Credit: Orbital Sciences' photo

[Enlarge Image](#)

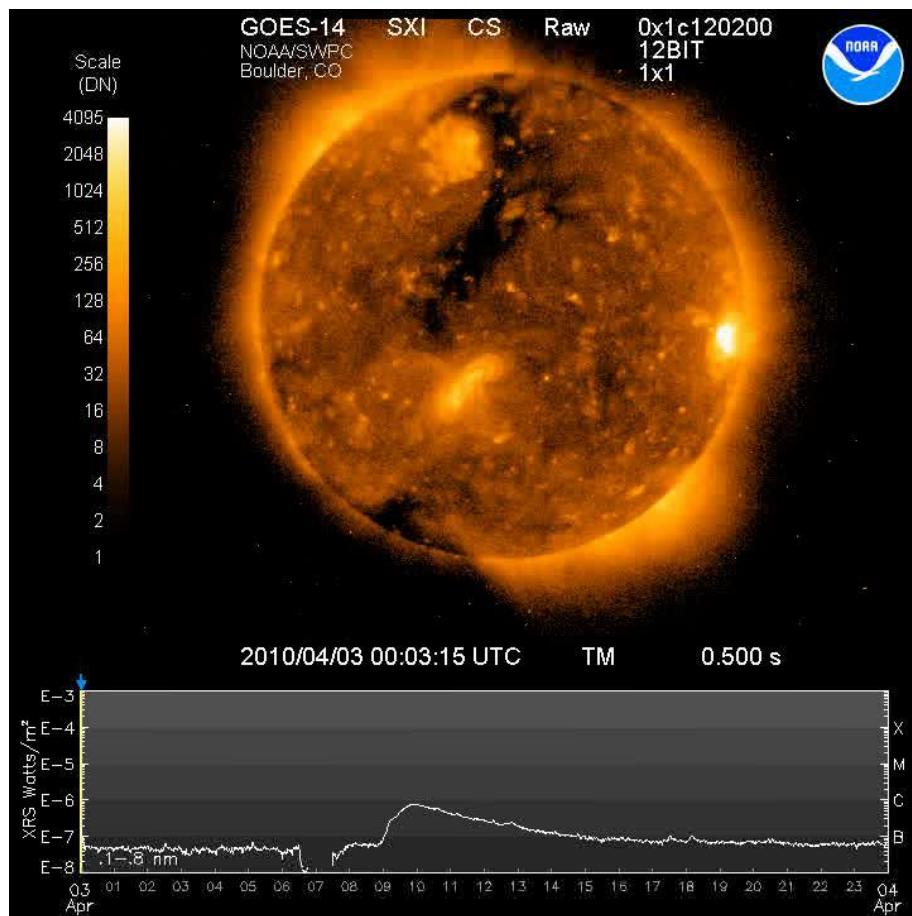


Galaxy 15 satellite. Photo Credit: Orbital Sciences

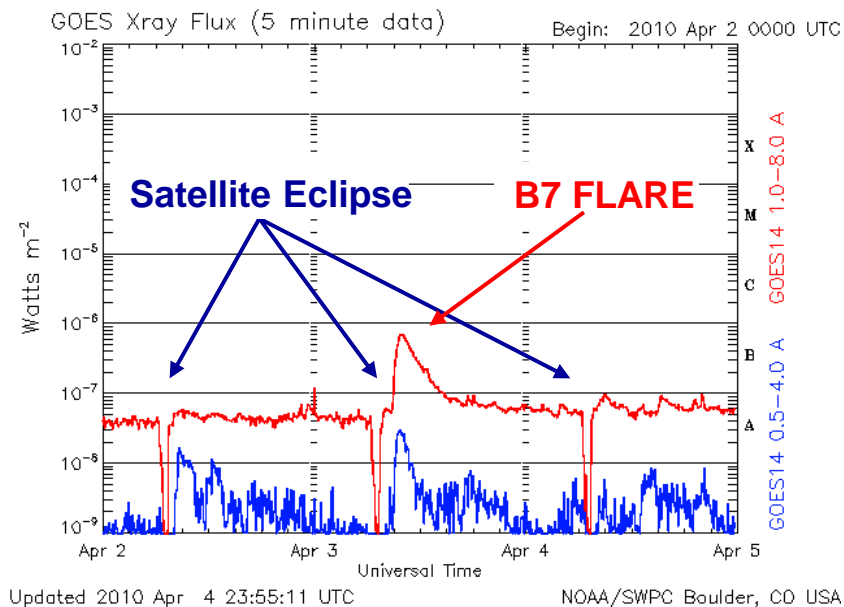
# Operational SWx Data

## Environmental Impacts – Case 1

### Galaxy 15 Satellite – Solar Observations



The initiation of the “solar storm” was a modest B7 solar flare from region 11059 (S22W15) that was observed on 02 April by the GOES X-Ray Sensor (XRS) and Solar X-ray Imager (SXI)



Additional data for this event available at: [http://sxi.ngdc.noaa.gov/sxi\\_greatest.html](http://sxi.ngdc.noaa.gov/sxi_greatest.html)

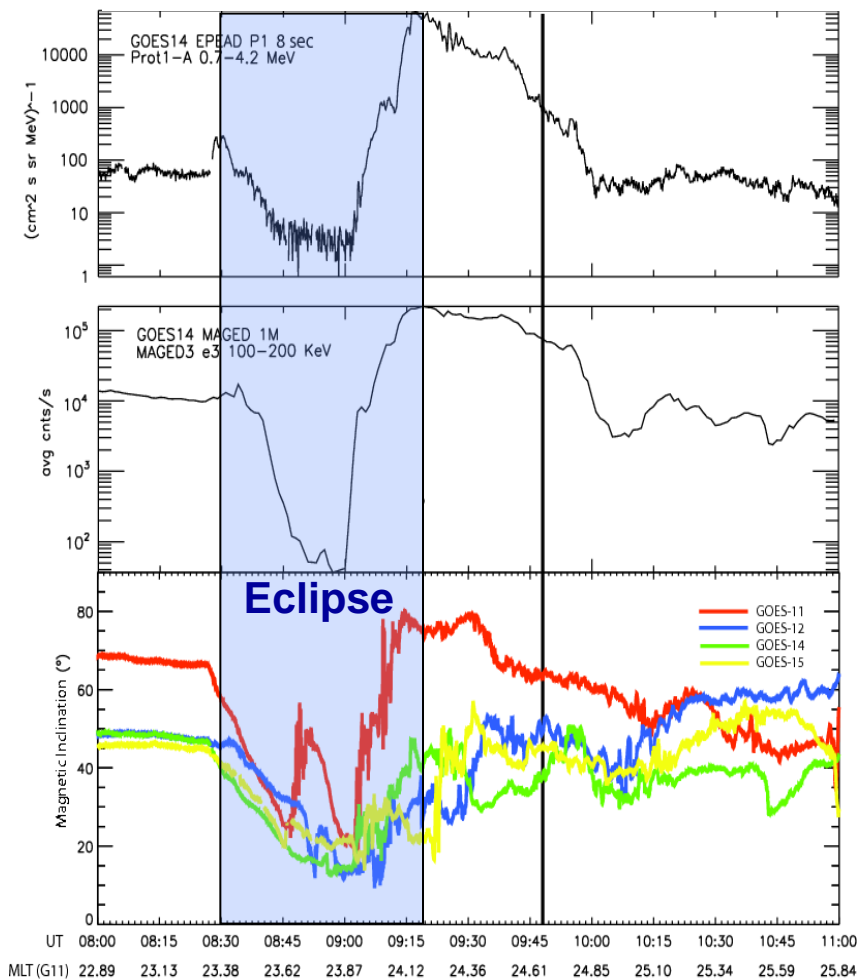


# Operational SWx Data

## Environmental Impacts – Case 1

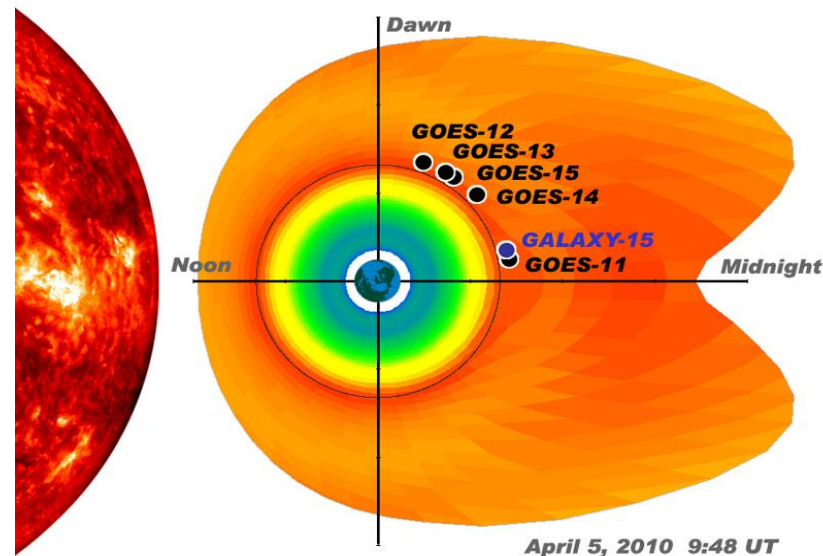
### Galaxy 15 Satellite – Local GEO Environment

#### Satellite Anomaly @ 9:48 UT



April 05 @ 09:00 UT: GOES sensors detected a major reconfiguration of the magnetosphere indicative of a magnetic storm.

#### Satellite Locations

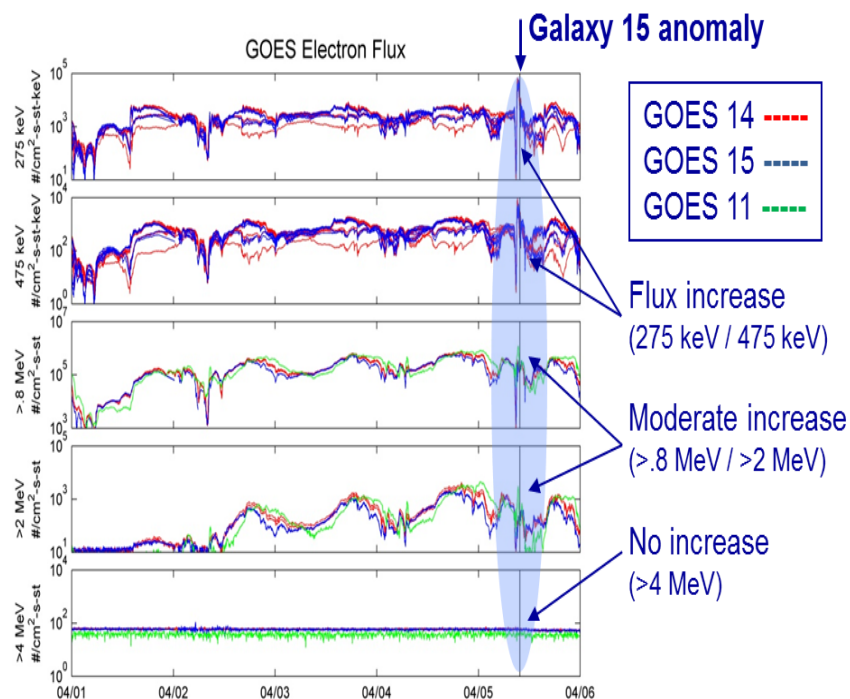


# Operational SWx Data

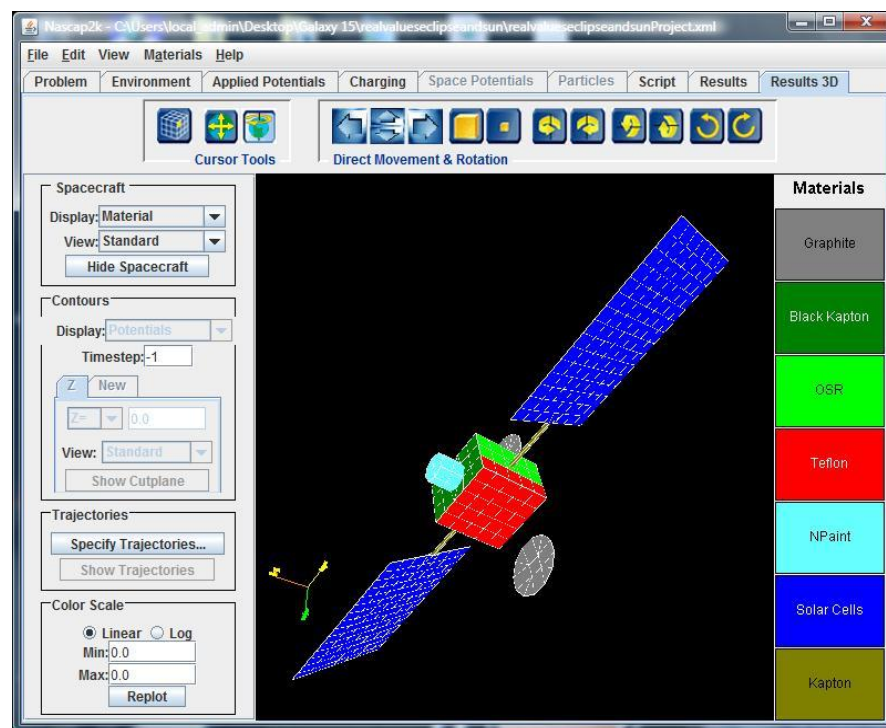
## Environmental Impacts – Case 1

### *Causal Indications – Internal Charging by Enhanced Electron Environment*

- Flux of 275-475 keV electrons was the highest observed since GOES 14 was turned on in July 2009 and GOES 15 since April 2010. GOES particle data used to model the charging environment experienced by the Galaxy 15 satellite noted extreme charging levels.



In-situ Particle Data



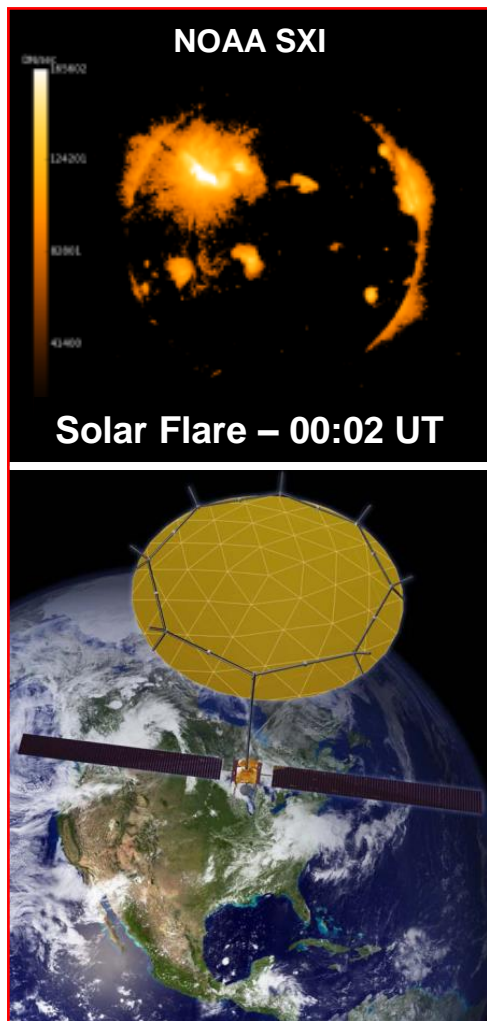
Use in Spacecraft Charging Models

# Operational SWx Data

## Environmental Impacts – Case 2

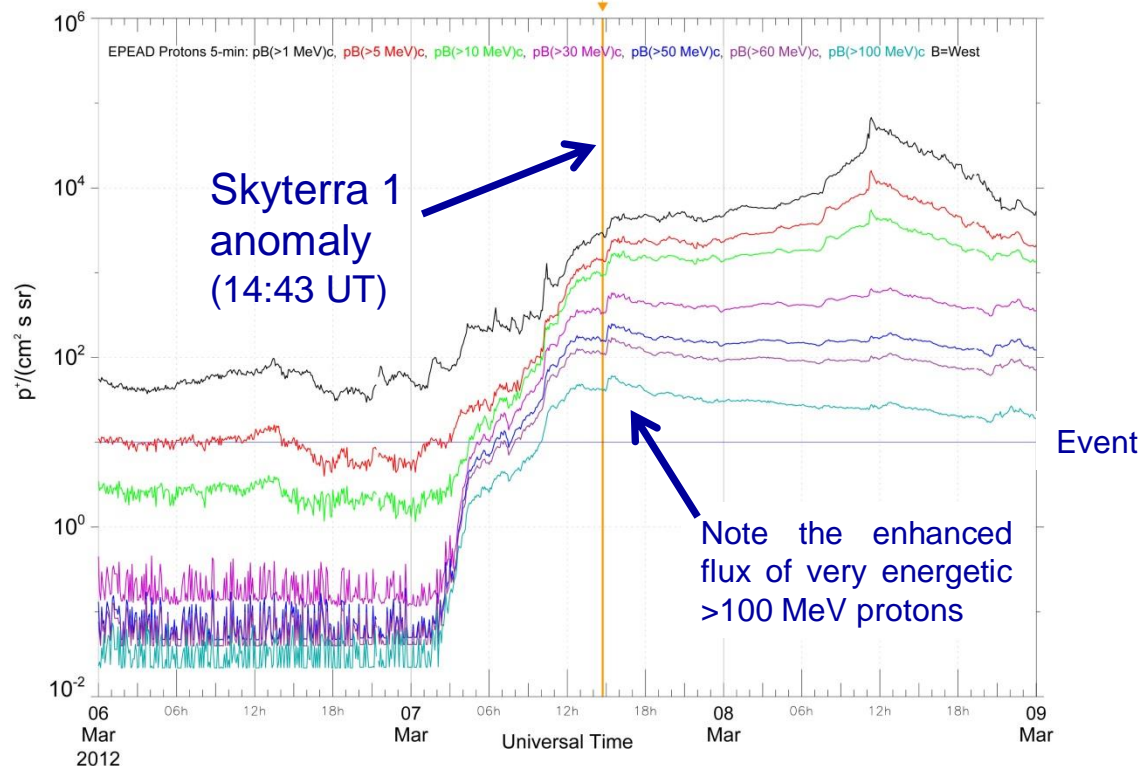
News Report: *Skyterra 1 satellite has been out of service since the solar storm on March 7*

<http://mobile.slashdot.org/story/12/03/15/199252/lightsquared-satellite-disabled-by-last-weeks-solar-storm>



The probable cause of the 07 March (2012) anomaly was a Single Event Upset (SEU) caused by a solar energetic proton (SEP) event from the X5 solar flare at active region 1429. An associated coronal mass ejection reached earth on 09 March.

GOES-15 Energetic Particles -- SkyTerra-1 Outage





# Operational SWx Data Topics

- Operational Satellite Datasets
- Environmental Impacts on Satellites
- **Where Have All the WDCs Gone?**



World Data Centers (1957 – 2008)

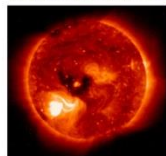
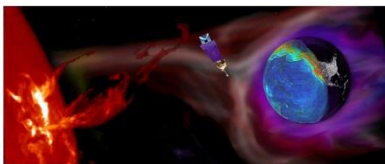


# Operational SWx Data World Data System

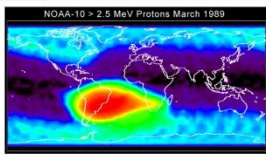
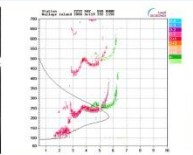
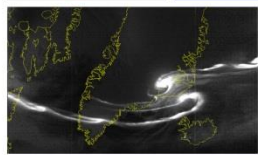
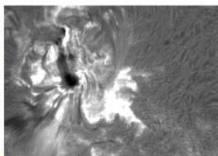


World Data Center for Solar-Terrestrial Physics  
Boulder, Colorado U.S.A.

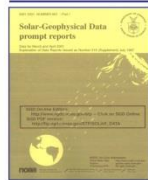
The World Data Center for STP, Boulder, traces its history to the 1957 IGY with the establishment of the WDC-A for Airglow and Ionosphere. Over the intervening years this WDC coalesced with the WDC-As for Aurora, for Cosmic Rays and for Solar Activity into the WDC-A for Upper Atmospheric Geophysics which, in 1972, was renamed the WDC-A for Solar-Terrestrial Physics. The WDC for Solar-Terrestrial Physics, Boulder is currently hosted at the National Geophysical Data Center (NGDC).



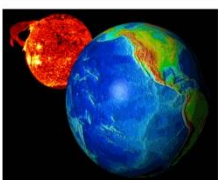
**Datasets** – WDC-STP holdings include significant volumes of solar-geophysical data in both digital and heritage formats. Key data sets include **solar data** from numerous ground-based observatories (1880 to present), **ionospheric data** from up to 405 ground ionosondes (1936-present), **geomagnetic indices** (1700-present), space-based **auroral imagery** (1992-present) and solar-geophysical data from operational **space weather satellites** (1974-present).



**Data Access, Products & Services** – Access to WDC-STP data holdings is via the world-wide web (www) for the digital datasets. The WDC supports various tools for data access, visualization and mining such as the Space Physics Interactive Data Resource (SPIDR), Satellite Archive Browse & Retrieval (SABR) and the Investigation of Distributed Environmental Archives System (IDEAS). WDC-STP also publishes the monthly Solar-Geophysical Data (SGD) reports (1955-present) as an overview and historic record of significant solar and geophysical events.



**Recommendations for future directions:** The WDCs have served a valuable and effective function for preserving geophysical datasets and for promoting international data exchange and user access. Whereas capabilities for data archive and access, search and discovery, and visualization have evolved significantly since the IGY the core principles of the WDC system remain the same. The WDC system should embrace and lead the development of new capabilities that strengthen the WDC core principles.



World Data Center for Solar-Terrestrial Physics • NOAA/NGDC • 325 Broadway • Boulder, Colorado 80305 • U.S.A.  
<http://www.ngdc.noaa.gov/wdc/>

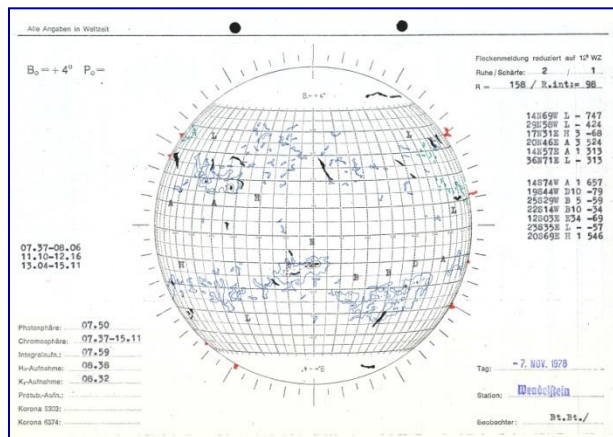
In 11/2008 the World Data Center (WDC) structure was officially disbanded and replaced by the World Data System (WDS). At that time, the WDC for Solar-Terrestrial Physics (WDC-STP, Boulder) transitioned into the WDS for Geophysics. For over 50 years the WDC-STP assembled environmental data on solar, ionospheric and geomagnetic observations, cosmic rays and related atmospheric phenomena. The WDS-Geophysics will continue to maintain and manage the unique environmental datasets collected since the International Geophysical Year (1957-58).



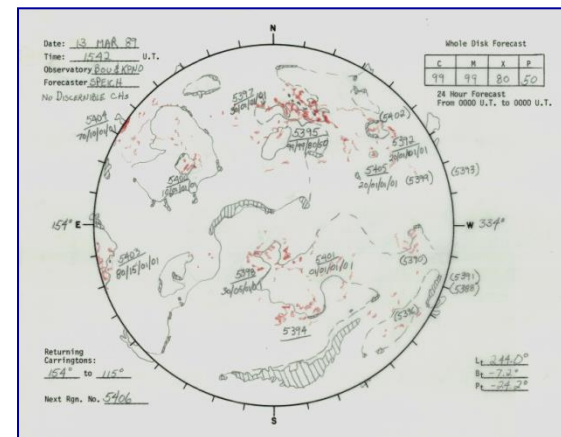
# Operational SWx Data

## WDS-STP – Solar Drawings & Images

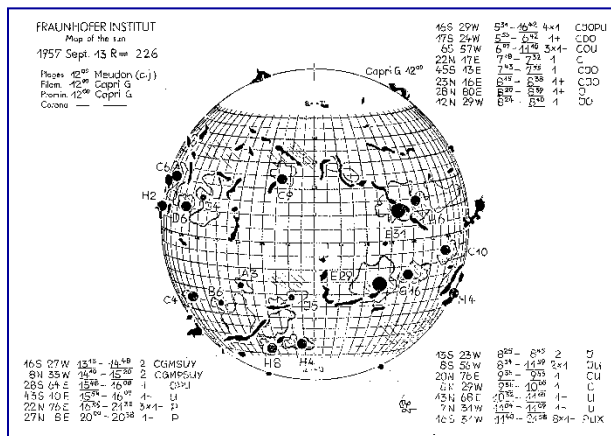
Historical solar archives assembled through the WDC-STP provide an historical record of the sun from 1947 to the present. Included are solar synoptic drawings, sunspot drawings, solar photographs, and other relevant data.



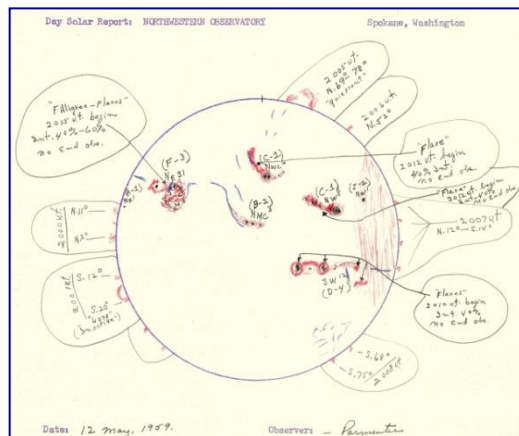
**Wendelstein Observatory  
(1947-1987)**



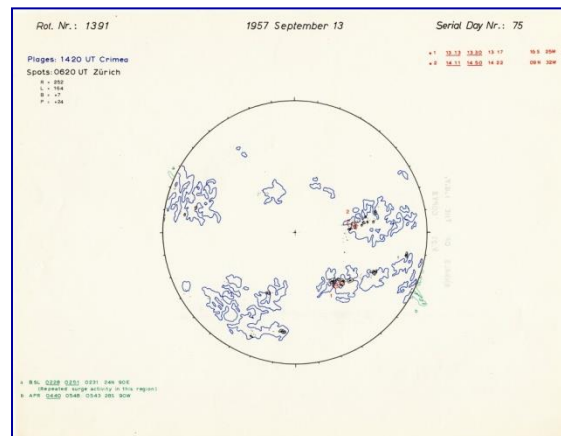
**Boulder Composite Drawings  
(1972-present)**



**Fraunhofer Institute  
(1956 - 1973)**



**Northwestern Observatory  
(1958 - 1970)**



**Drawings from the IGY  
(1957 - 1958)**





# Operational SWx Data

## WDC-STP – Indices



### GEOMAGNETIC INDICES BULLETIN

MARCH 2012

National Geophysical Data Center  
Solar-Terrestrial Physics Division  
325 Broadway (E/GC2)  
Boulder, CO 80305-3328

Telephone: 303-497-6135  
fax: 303-497-6513  
www.ngdc.noaa.gov

**THE GEOMAGNETIC FIELD.** The geomagnetic field measured at any point on the Earth's surface at any time is a combination of the MAIN field internal to the planet, of fields arising from electrical currents flowing in the ionized upper atmosphere, and of fields induced by currents flowing within the Earth's crust. The main field component varies slowly in time and can be grossly described as that of a bar magnet with north and south poles deep inside the Earth and magnetic field lines that extend well out into space.

The main field creates a cavity in interplanetary space called the magnetosphere, where the Earth's magnetic field dominates the magnetic field of the solar wind. The magnetosphere is shaped somewhat like a comet in response to the dynamic pressure of the solar wind. It is compressed on the side toward the sun to about 10 Earth radii and is extended tail-like on the side away from the sun to more than 100 Earth radii. The magnetosphere deflects the flow of most solar wind particles around the Earth, while the geomagnetic field lines guide charged particle motion within the magnetosphere.

The differential flow of ions and electrons inside the magnetosphere and in the ionosphere form current systems, which cause variations in the intensity of the Earth's magnetic field. These EXTERNAL currents in the ionized upper atmosphere and magnetosphere vary on a much shorter time scale than the INTERNAL main field and may create magnetic fields as large as 10% of the main field.

Daily regular magnetic field variations arise from current systems caused by regular solar radiation changes. Other irregular current systems produce magnetic field changes caused by the interaction of the solar wind with the magnetosphere, by the magnetosphere itself, by the interactions between the magnetosphere and ionosphere, and by the ionosphere itself. Magnetic activity indices, including those below, are designed to describe variations in the geomagnetic field caused by these irregular current systems.

#### MONTHLY SUMMARY OF GEOMAGNETIC ACTIVITY FOR MARCH 2012

Day		Rank		Kp Three-Hour Indices								Kp		Sc <sup>+</sup>		As Provisional	
Cal	Year	Bar	Q/D	1	2	3	4	5	6	7	8	Sum	Ap	Cp	(UT)	An	As
1	61	22		0+	3	4-	4-	3-	3-	4-	4-	24	17	0.9		33	34
2	62	23		3	3	2-	2-	3-	2	2	2	19	10	0.6		20	17
3	63	24	Q9	2+	2+	2+	2	1-	3-	1	2	15+	8	0.4		17	16
4	64	25		4-	3	3	2+	2+	2-	3	2	21-	12	0.7		25	21
5	65	26		3-	2	2	2+	1+	2-	3-	3+	18	10	0.5		18	16
6	66	27		3	2	3-	1-	3-	2	2	3-	18-	9	0.5		19	20
7	67	1	D2	4-	5-	6-	6-	5+	5+	5-	4	39+	48	1.6	0420	69	76
8	68	2		2	1	2-	5	5-	5-	4	4	27	25	1.2	1103	42	35
9	69	3	D1	5-	6+	8	7+	7-	6-	3	2+	44	87	1.8		18	9
10	70	4		5-	5-	3+	3-	2	3	3+	1+	25	19	1.0		31	29
11	71	5		2	2-	1	2-	2+	3-	3	3+	18-	10	0.5		19	17
12	72	6	D4	3	2-	2+	6+	6	4-	3+	3	29+	32	1.3	0915	45	43
13	73	7		4-	3+	1+	1+	2	2-	2	2-	17	10	0.5		18	17
14	74	8		3-	2	1	1	2	3	2	2+	16	8	0.4		16	14
15	75	9	D3	4-	3-	2	2	5-	6+	5	5+	32-	36	1.4	1307	54	53
16	76	10	D5	4+	3+	3	4+	3+	5	4	4-	31	26	1.2		42	48
17	77	11		4	4	4-	3-	3-	4+	4+	5	31-	26	1.2		40	42
18	78	12		4	4-	2+	2+	2-	2+	3	3	21	13	0.7		20	19
19	79	13		2	4-	2	2-	2+	1+	2+	3	18	10	0.5		20	20
20	80	14	Q5	1+	1-	1	1+	1-	1	2	2	10	5	0.2		8	12
21	81	15	Q7	1+	1	1	1	2-	1	2+	2-	11-	5	0.2		11	14
22	82	16	Q10	1-	2-	0+	0+	0+	3+	4	10+	7	0.4			11	10
23	83	17	Q8	3	1	1+	1	1	2-	1	0	9+	5	0.2		8	9
24	84	18		1+	3	4+	3-	2	2	2-	2	19	11	0.7		20	18
25	85	19	Q3	2-	1	2-	1+	2-	1	0	0	8-	4	0.1		8	7
26	86	20	Q1	1-	1+	1	1	1-	1-	0+	1	7-	4	0.1		5	5
27	87	21		3	2-	2-	3-	3	3	3+	5	23+	17	0.9		23	26
28	88	22		5-	4+	3-	2-	2+	1+	2+	1+	21-	15	0.8		24	32
29	89	23	Q2	0	0	0	0	1+	1	1+	2+	6	3	0.0		6	4
30	90	24	Q6	3-	2	1+	1	1	1	0	0	9-	4	0.2		8	8
31	91	25	Q4	0+	0+	0+	1-	2-	2	2+	0+	8	4	0.1		8	6
Mean												16	0.67			23	23

\*preliminary

Column headings defined on back side.

### SOLAR INDICES BULLETIN

FEBRUARY 2011

NATIONAL GEOPHYSICAL DATA CENTER  
Solar-Terrestrial Physics Division (E/GC2)  
Telephone (303) 497-6346

325 Broadway  
Boulder, Colorado 80305-3328 USA  
ISSN 1046-1914

#### ♦ SOLAR RADIO EMISSIONS

The quiet Sun emits radio energy with a slowly varying intensity. These radio fluxes, which stem from atmospheric layers high in the chromosphere and low in the corona, change gradually from day-to-day, in response to the number and size of spot groups on the solar disk. The table below gives daily measurements of this slowly varying emission at selected wavelengths between about 1 and 100 centimeters. Many observatories record quiet-sun radio fluxes at the same local time each day and correct them to within a few percent for factors such as antenna gain, bursts in progress, atmospheric absorption, and sky background temperature. At 2800 megahertz (10.7 centimeters) flux observations summed over the Sun's disk have been made continuously since February 1947.

#### ♦ SOLAR FLUX TABLE

Numbers in parentheses in the column headings below denote frequencies in megahertz. Each entry is given in solar flux units—a measure of energy received per unit time, per unit area, per unit

frequency interval. One solar flux unit equals  $10^{-22}$  J/m<sup>2</sup>Hzsec. During periods of low solar activity, the flux never falls to zero, because the Sun emits at all wavelengths with or without the presence of spots. The lowest daily Ottawa flux since 1947 occurred on November 3, 1954. On that day the observed noon value dropped to 62.6 units; the highest observed value of 457.0 occurred on April 7, 1947.

The preliminary observed and adjusted Penticton fluxes tabulated here are the "Series C" values reported by Canada's Dominion Radio Astrophysical Observatory in Penticton, British Columbia. Observed numbers are less refined, since they contain fluctuations as large as 7% from the continuously changing sun-earth distance. Adjusted fluxes have this variation removed; they show the energy received at the mean distance between the Sun and Earth. Gaps in the Palehua, Hawaii (PALE), data reflect equipment problems. Fluxes measured either at Sagamore Hill, Massachusetts, or at San Vito, Italy, will be substituted for frequencies at which many Palehua values are missing.

FEBRUARY 2011 PRELIMINARY SUNSPOT NUMBERS AND SOLAR RADIO FLUX															JAN 2011 FINAL FLUX			
Day	Sunspot Number	Obs Flux Pentic (2800)	Solar Flux Adjusted to 1 Astronomical Unit								Observed Pentic (2800)	Adjusted Pentic (2800)						
			PALE (1540)	PALE (8800)	PALE (4955)	Pentic (2800)	PALE (2695)	PALE (1415)	PALE (610)	PALE (410)			PALE (245)					
01	15	80	545	227	124	77	73	67	41	31	13							
02	13	79	529	227	124	76	72	67	41	32	12	91.1	88.1					
03	18	80	534	227	127	77	72	67	42	32	12	92.1	89.1					
04	22	82	536	224	127	79	73	68	42	33	14	90.6	87.6					
05	16	81	532	226	127	78	73	68	42	33	15	87.7	84.8					
06	9	80	480	230	126	77	72	67	42	33	15	* - Not Available						
07	9	82	531	227	128	79	76	69	42	33	15	86.8	83.9					
08	39	90	540	239	138	87	85	76	45	36	—	84.8	82.0					
09	31	89	537	235	137	86	80	73	45	34	16	82.7	80.0					
10	21	91	540	238	133	88	83	77	45	36	14	83.3	80.6					
11	35	91	536	233	135	88		77	46	35	16	82.6	79.9					
12	37	96	539	239	142	93	90	81	49	37	15	80.0	77.4					
13	48	107	—	—	—	104	—	—	—	—	—	79.5	76.9					
14	53	113	577	273	154	110	102	88	—	—	—	79.3	76.7					
15	51	113	541	251	161	110	101	90	51	36	24	80.2	77.6					
16	48	114	545	255	162	111	103	91	53	47	—	80.3	77.8					
17	40	111	546	247	159	108	101	91	50	37	22	81.8	79.1					
18	49	125	544	255	166	122	110	95	72	74	—	81.0	78.4					
19	50	109	538	247	155	106	97	87	49	36	17	80.8	78.2					
20	42	105	538	238	145	102	94	81	47	35	16	82.3	79.7					
21	29	87	537	236	140	94	90	77	46	34	16	87.5	84.8					
22	23	91	530	233	136	88	84	73	—	—	—	87.7	84.9					
23	19	89	568	252	131	87	82	70	44	35	16	84.3	81.7					
24	13	89	569	247	129	87	81	68	44	33	16	82.5	79.9					
25	10	88	288	210	121	86	79	66	42	31	14	80.5	78.0					
26	26	90	567	251	127	88	85	70	42	33	14	80.0	77.6					
27	27	90	552	251	129	88	84	70	43	32	14	80.5	78.1					
28	31	96	356	222	125	94	87	72	41	29	13	80.6	78.1					
												81.4	79.0					
												82.6	80.2					
												81.3	78.9					
Mean	29.4	95	525	239	137	92	86	76	46	36	15	83.4	80.8					

Radio data for 14, 23-28 are from Sagamore Hill.

Geomagnetic Indices Bulletin: <http://www.ngdc.noaa.gov/stp/geomag/geoib.html>

Solar Indices Bulletin: <http://www.ngdc.noaa.gov/stp/solar/sibintro.html>



# Operational SWx Data

## WDC-STP – Historical Documents



SPACE WEATHER, VOL. 10, S05007, doi:10.1029/2012SW000802, 2012

### Historical Upper Atmosphere Geophysics Reports Now Available Online

J. H. Allen, C. A. Clark, W. F. Denig, and D. C. Wilkinson

Published 26 May 2012

Citation: Allen, J. H., C. A. Clark, W. F. Denig, and D. C. Wilkinson (2012), Historical upper atmosphere geophysics reports now available online, *Space Weather*, 10, S05007, doi:10.1029/2012SW000802.

On 29 November 2011, NOAA's National Geophysical Data Center (NGDC) published the 1968–1996 series of the Upper Atmosphere Geophysics (UAG) reports online at <http://www.ngdc.noaa.gov/stp/solar/onlinepubl.html>. This 105-volume series contains reports on unusual occurrences in the near-Earth space environment, on specialized data collections, and on other records and materials of interest to the solar-terrestrial physics community.

The report likely to generate the most interest may be UAG-28, *Collected Data Reports on August 1972 Solar-Terrestrial Events*, which provides contemporary accounts of these classic events as experienced and recorded by leading space scientists. The 932-page, three-part report is a compilation of scientific articles contributed by 336 researchers in 156 separate papers. Technical compilations on other notable space weather events, including those in May 1967 (UAG-5), October–November 1968 (UAG-8, UAG-9), November 1969 (UAG-13), March 1970 (UAG-12), and January and September 1971 (UAG-24), are also available in this series.

The UAG reports have, in general, covered space environment phenomena ranging from Jovian radio bursts to disappearing solar filaments. These phenomena have sometimes disrupted and even damaged technical systems in space and on the ground. Thus, the reports contain important historical information on the space weather conditions in effect when these systems were compromised. Other UAG reports provide a long-term perspective on various types of instrumentation and techniques for monitoring space weather, including the use of magnetometers, ionosondes, and solar electro-op-

tical telescopes.

These UAG reports complement the monthly Solar Geophysical Data (SGD) reports published by NGDC between 1955 and 2009 as a 54-year record of solar, interplanetary, and near-Earth space environment events. The full set of SGDs, widely known as the “yellow book” series, is also available from NGDC at the Web address given above.

Both the UAGs and SGDs are testaments to the insight and dedication to data preservation of J. Virginia Lincoln and other early space scientists whose pioneering efforts laid the foundation on which the current space weather enterprise is built.

**J. H. Allen** served as Chief of the Solar and Terrestrial Physics Division at NOAA's National Geophysical Data Center from 1979 until his retirement in 1994. ([Joe.H.Allen@noaa.gov](mailto:Joe.H.Allen@noaa.gov))

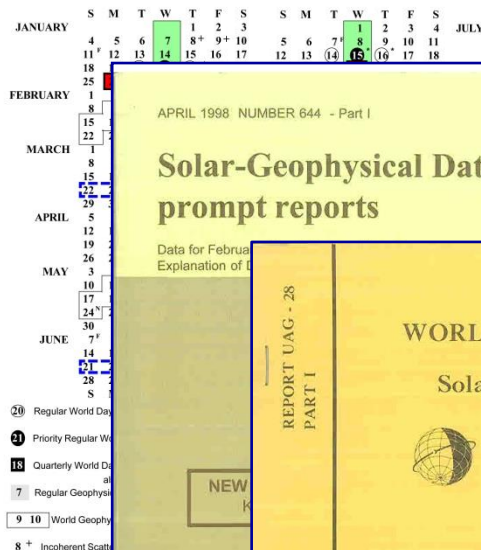
**C. A. Clark** works in the Indices and Solar Images Group of the Solar and Terrestrial Physics Division at NOAA's National Geophysical Data Center, in Boulder, Colo. ([craig.a.clark@noaa.gov](mailto:craig.a.clark@noaa.gov))

**William F. Denig** is the current Chief of the Solar and Terrestrial Physics Division at NOAA's National Geophysical Data Center. ([William.Denig@noaa.gov](mailto:William.Denig@noaa.gov))

**D. C. Wilkinson** is a physicist at the Solar and Terrestrial Physics Division at NOAA's National Geophysical Data Center. ([daniel.c.wilkinson@noaa.gov](mailto:daniel.c.wilkinson@noaa.gov))

### International Geophysical Calendar 2009 (FINAL)

(See other side for information on use of this Calendar)



### Solar-Geophysical Data prompt reports

Data for February  
Explanation of

REPORT UAG - 28  
PART I

### WORLD DATA CENTER A for Solar-Terrestrial Physics

COLLECTED DATA REPORTS  
ON  
AUGUST 1972 SOLAR - TERRESTRIAL EVENTS

JULY 1973



# Operational SWx Data Summary



- Space environmental data available from operational satellites and other platforms can be leveraged for space weather research
- Available environmental data can be used for post event analysis of spacecraft anomalies
- World Data System has now replaced the World Data Centers and is responsible for continued historical data preservation